Multiphysics Simulation Of Internal Discharge In Nanodielectrics

Farzana Alam[1], Md. Afzalur Rab[2]

[1]UnitedHealth Group, Philadelphia, PA, USA

[2]Center for Materials Research, Norfolk State University, Norfolk, VA 23504

ABSTRACT

This research work investigates the effect of inclusion of small amount (0%, 2% and 6%) of natural Nano fillers on the internal field properties and discharge characteristics of polypropylene films.2D and 3D Models are built to simulate field properties and internal charge in natural nanofillled dielectric and insulation. Internal discharge causes gradual deterioration of a dielectric material and may cause failure of the sample. So, modeling and simulation of internal field distortion in Nanodielectrics is of great interest. . Numerical computation and evaluation were done on properties.

INTRODUCTION

Polypropylene is a commonly used materials in power industry due its superior dielectric properties. When polypropylene is used in power apparatus, under HV, the insulation goes through a number of issues such as internal materials degradation, internal discharges, insulation breakdown etc. Discharge creates space charges that can distorts internal field, and lead to degradation inside the insulating materials. Nanoparticle can solve these issues if controlled amount of nanoparticle is used.

MOTIVE

To find a solution to improve dielectric properties such as decrease in space charge of Nanocomposites by building 3D model and simulate. Investigate change in internal electric field due to incorporation of nanofiller is another objective. Then use obtained simulation results to explain real experimental results achieved from application of high voltage to dielectric insulation.

SAMPLE AND SET UP

Isotactic Polypropylene film with organic natural Nanoparticles were used in multiphysics simulation. The thicknesses of the nanofilled micro film were 135µm. The diameter of Nanoparticles were less than 100nm. Two plane-plane copper electrodes were used to apply high voltage and ground respectively.

BUILDING 3D AND 2D MODELS

Figure 1 shows the built 3D model for simulation. A Plane-Plane electrode system was used to apply electrical stress to the samples. Circular samples of diameter 10cm were perfectly attached between two electrodes. The boundary conditions are top electrode, =10kV, ground electrode, V=0V.

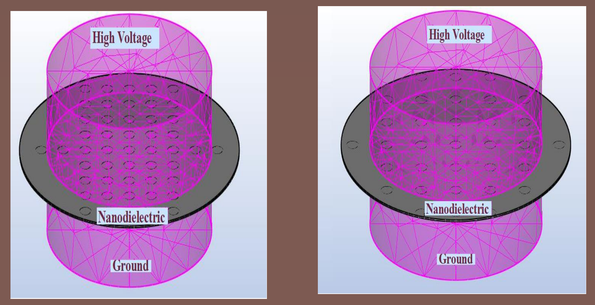

Figure 1 : Meshing in Nanofillled polypropylene under HV with (a) 4% Nanoparticle and (b) 1% Nanoparticle

The second set up with a 2D plane-plane electrode system having same thin polypropylene film filled with Nanoparticles have been used. Here the thin sample is the films incorporating Nanoparticles.

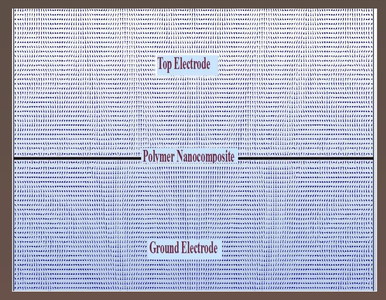

Figure 2(a). Field Arrow in 2D Model of Nanodielectrics in plane-plane electrode system

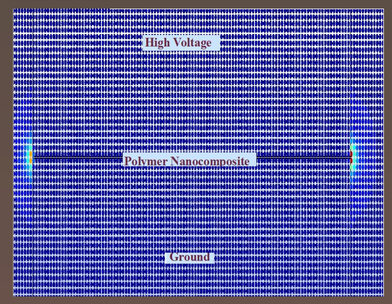

Figure 2(b). E-Field Scatter in nanoparticle filled (4%) sample

SIMULATION, RESULT AND ANALYSIS

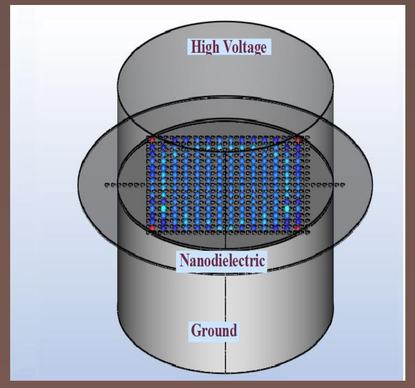

Figure 3(a). Electric Field Scatter in (a) 4% nanofillled sample

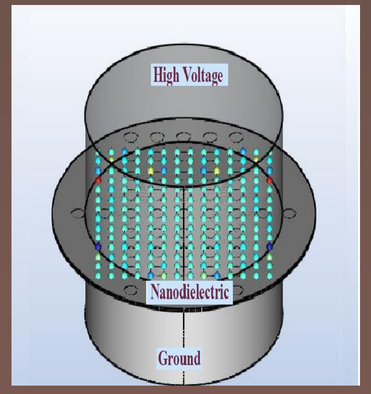

Figure 3(b). Electric Field Scatter in (a) 1% nanofillled sample

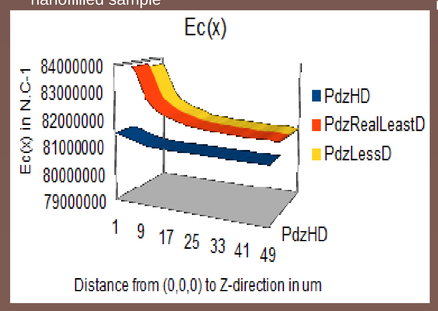

Figure 4(a). Electric Field with the presence of space charge under the Applied Voltage

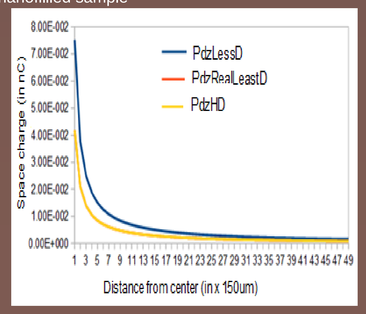

Figure 4(b). Space charge under the Applied Voltage

In figure 2(b) field scatter is exhibited in edges of sample only.
In figure 3, blue color indicates less scatter in electric field and green color indicates high scatter in electric field.
In figure 4(a), internal field becomes lowest for 4% nanoparticle concentration and higher for least or 0% concentration

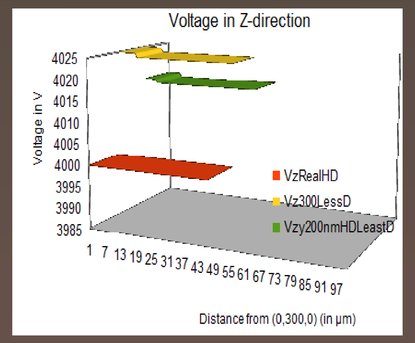

Figure 5(a). Voltage from (0,0,300nm) to Z-directions in samples in presence of space charge

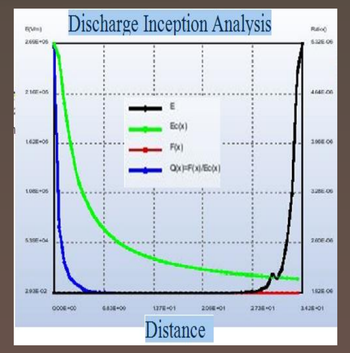

Figure 5(b): Discharge inception, Electric field and Force relationship

HV was applied from top plane electrode to the nanofillled micrometer thick sample and variation in output voltage within the sample for different concentration of nanoparticle has been investigated. Results indicate that for 4% concentration the internal voltage becomes lower. Higher concentration can sustain higher electrical stress.

Internal discharge inception analysis shows relationship among space charge, internal field and electrostatic force. From sample center to the edges in Z direction , both Q(x) and Ec(x) decreases with increases in distance. The relationship is observed at a certain applied voltage which is greater than 4kV. Below that voltage, no discharges occur. This is why, it is kwon as inception analysis.

CONCLUSIONS

- 2D and 3D models of Nanodielectrics for internal discharge simulation are built
- Boundary conditions were applied at top cylindrical electrode=any HV, ground=0V.
- Various electrical properties such as voltage contour, electric field density, voltage scatter, electric field contour have been simulated.
- Simulated results are shown.
- Analysis has been performed.

ACKNOWLEDGEMENT

I am sincerely grateful to Air Force of Scientific Research (AFOSR) (FA9550-18-1-0417) for sponsoring my research.

REFERENCES

1. Nelson. K., “Dielectric Polymer Nanocomposites,” Springer Publications (2009)
2. Fothergill. J. C., Nelson J. K. and Fu. M., “Dielectric properties of epoxy nanocomposites containing TiO2, Al_2O_3 and ZnO fillers,” IEEE CEIDP, pp. 406-409 (2004).
3. Poda. A. B., Basappa. P., and Fritzel. S. C., “Analyses of Surface Degradation of Nano-filled Polypropylene Films through Partial Discharges & Surface Study,” IEEE Electrical Insulation Conference, (2013).
4. Bulinski. A., Bamji. S. S., Dakka M. A., and Chen. Y., “Dielectric Properties of Polypropylene Containing Synthetic and Natural Organoclay,” Conference record of IEEE Internal Symposium on Electrical Insulation, pp. 1-5, (2010).